USING MINIATURE-SCALE HIGH-EXPLOSION EXPERIMENTS TO STUDY WEAPON EFFECTS

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Introduction

Recently, the U.S. Army Engineer Waterways Experiment Station (WES) began a program to develop methods that will allow battlefield explosion effects to be replicated at "miniature-scale." Miniature-scale explosion experiments use a few tens of grams of explosives and are performed, figuratively, "on a desktop." They can replicate and replace many large-scale explosion field experiments that use many kilograms of explosives. They make use of explosive sources that are on the order of tens of grams of TNT explosive equivalent or less, and typically have length scales relative to a prototype event of 1/10 to 1/1000. They are conducted over periods of days as opposed to the months required for large-scale experiments, and they cost tens of thousands of dollars as opposed to hundreds of thousands or millions of dollars. Similitude theory is used in the design of miniature-scale experiments and in the interpretation of their results. In many cases, miniature-scale experiments, in combination with numerical simulations and verifying field experiments, provide the most cost-effective and expeditious method to develop an understanding of explosion phenomena. This article describes the cratering experiments performed by WES and the potential impact of miniature-scale explosion experiments on future military research.

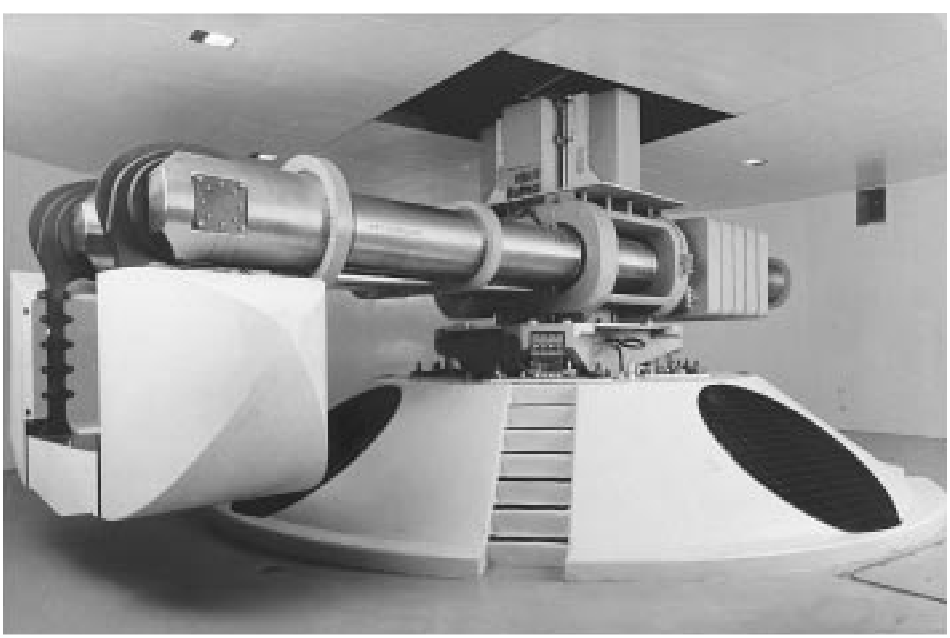


Figure 1.
U.S. Army centrifuge.

Background

High-explosion experiments are used for studying weapon effects and the response of structures to these effects. Historically, these have been large-scale experiments, using tens or hundreds of kilograms of explosives. The scale of an explosion experiment refers to the relationship between the experiment and the event it models, and usually refers to length scale. For example, a one-half-scale cratering experiment would produce a crater with one-half the diameter and one-half the depth of a prototype cratering event.

Numerical simulations can be used to reduce the number of large-scale explosion experiments necessary to predict the explosion-induced flow fields and their interaction with surrounding environments and structures. But numerical simulations cannot eliminate the need for experiments because of assumptions involved in numerical modeling. Thus, although there have been significant improvements in modeling explosion effects using numerical simulations, explosion experiments are necessary to verify these simulations.

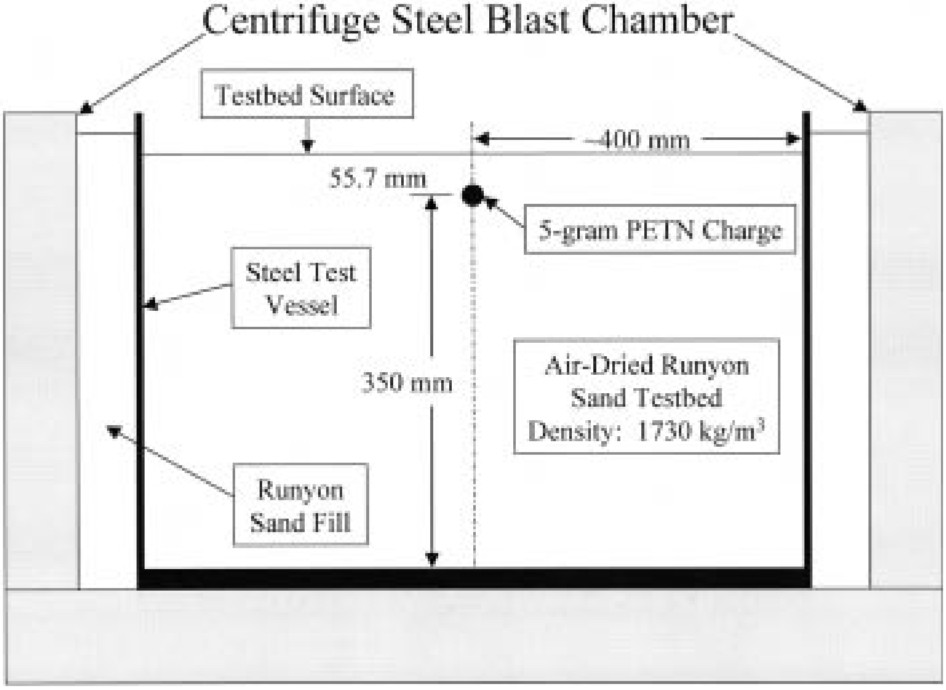


Figure 2.
Cross-sectional geometry for laboratory-scale experiment.

Miniature-scale explosion experiments have the potential to greatly reduce the time and money needed to predict the outcome of a wide variety of detonation scenarios.

The mechanics governing effects from explosions do not necessarily break down with significant changes in scale. Those instances in which the mechanics do not break down provide an opportunity to replace large-scale experiments with small-scale experiments.

Miniature-Scale Cratering Experiments

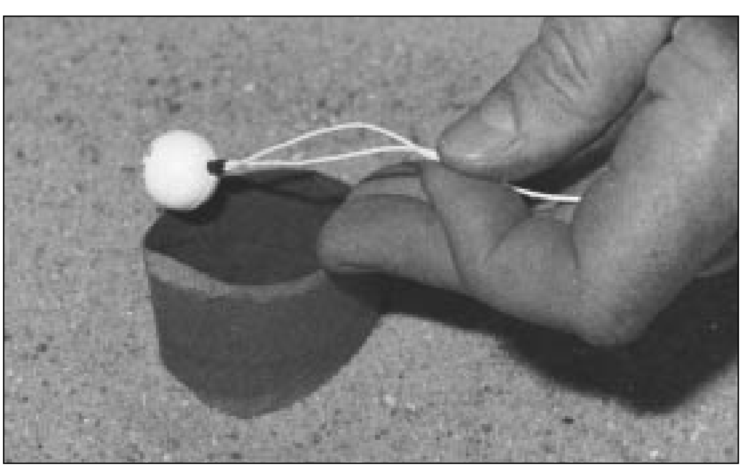
During the past few months, WES conducted three miniature-scale explosion experiments to model several phenomena, including cratering. The newly completed Army Centrifuge (Figure 1) was used to conduct these experiments. In particular, a large-scale cratering and ground-shock field experiment used a center-detonated, 454-kilogram nitromethane spherical explosive charge detonated at a 2.5-meter depth in a testbed of sand (Socorro plaster sand). Figure 2 shows a cross section of the geometry used in model crater experiments. The Army Centrifuge is the world's most powerful and allows geologic samples of up to 2,000 kilograms to be exposed to explosion effects while under gravitational fields of up to 350 Earth gravities. Cratering phenomena are long-term response phenomena and are significantly affected by the gravitational conditions under which the craters are formed.

The model testbeds were constructed from a local sand (Runyon Sand), which has gradation and mechanical properties similar to that used in the field experiment. The sand was air-dried, sieved, and then placed in a steel chamber with the same density as in the prototype event.

Figure 3 shows one of the precision 5-gram, center-detonated, PETN explosive charges being placed in a model testbed. The linear scale of the experiment was set by the cube-root of the ratio of the mass of the prototype explosive charge to the precision charge mass (See B. Hopkinson, British Ordnance Minutes, 13565, 1915). This resulted in the linear scale between prototype and model of 44.9.

Figure 4 displays the average crater profile from each of the three model experiments, scaled to the prototype event, along with the prototype crater profile. The model experiments showed good repeatability (precision), and they replicated the prototype crater with reasonable accuracy. The primary differences seen between the replica craters and the prototype crater are attributed to inaccuracies in the hand measurements of the small replica

Figure 3.
Precision 5-gram explosive charge.



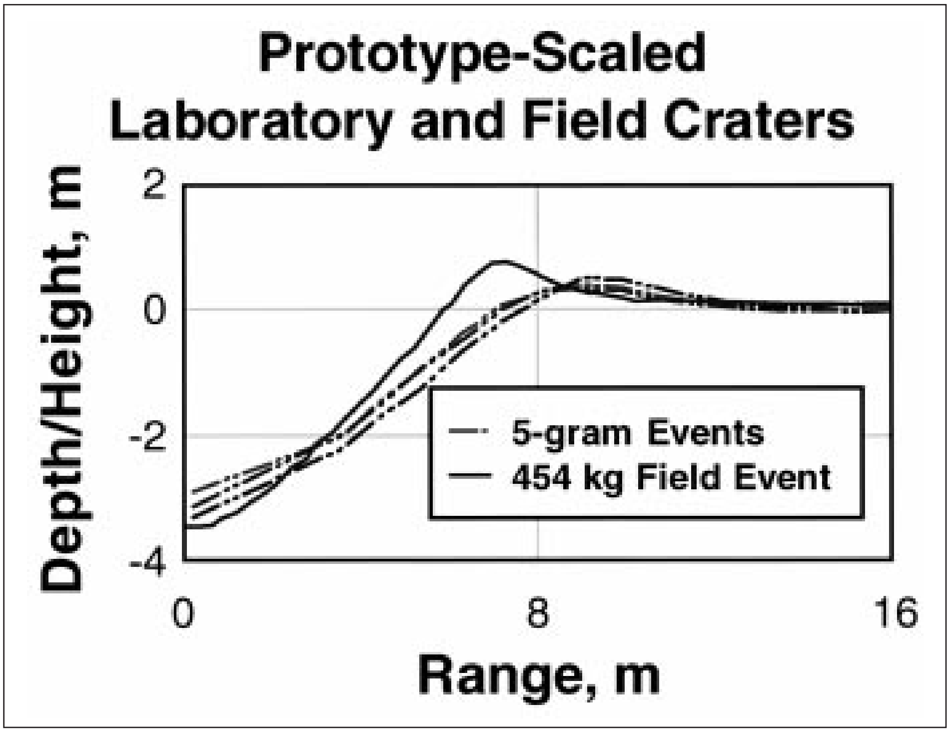


Figure 4.
Crater profiles from model and field events.

craters. A laser-based surface profiler currently being procured should reduce this problem.

The 454-kilogram prototype event included an extensive ground-motion array that was not included in the miniature-scale experiments. Had the prototype event not included the ground-motion array, it is estimated that it would have taken more than 1 month to conduct and would have cost more than $100,000. Each centrifuge experiment took less than 3 days to conduct and cost about $10,000.

Conclusion

Miniature-scale explosion experiments have the potential to greatly reduce the time and money needed to predict the outcome of a wide variety of detonation scenarios. While some large-scale experiments will be needed in the future, the number will likely decrease, and the purpose for many will be to verify what was determined via a combination of miniature-scale experiments and numerical simulations.

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